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Design of Visualization Interface for Transmission Congestions

Yuan-Kang Wu[a,] *, Xiu-Chang Lee[a], Che-Yi Hu [a], Po-En Su[a]

[a]*National Chung-Cheng University, No.168, 62102 Chiayi, Taiwan*

Abstract

Visualization has been extensively applied in many areas, especially for the management of massive data and the display interface area. However, the complexity of grid connections in a large-scale power system is a challenging issue. For an efficient power system operation, it is necessary for electrical engineers and operators to analyze huge amount of data. Additionally, providing real-time operating status and visualization to system operators is also significant. This work reviews different types of power system visualization techniques, including power-flow visualization, trend charts, pie chart, area chart, and warnings in colors. This work also developed a visualization interface that displays the transmission system congestions for N-0 steady state and N-1 contingency analyses. The developed visualization interface has been applied to the Taiwan power system by considering real system parameters and operating conditions, and the developed visualization techniques include the plot for displaying real-time transmission system operation, status warning, and N-1 system contingencies. The developed visualization interface helps system operators understand the real-time operating conditions and determine the potential schedules for generation and transmission systems.

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Keywords: Visualization techniques, Power system, Transmission system congestions

1. Introduction

A power system operation requires the analysis of large amount of data and the ability to cope with the change of different operating situations within the system. In the past, these data have been displayed as texts, trend plots or one-line diagrams. Users can read the text clearly, but it is hard to detect the trend of data. The trend plot can show the trend of system parameters in interest, but cannot reveal the status of a whole system. One-line diagrams can show the status of a whole system, but it is independent from the time and cannot express the exactly location of

* Corresponding author. Tel.: +886-939500016.
E-mail address: allenwu@ccu.edu.tw

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each bus. Therefore, some visualization techniques in modern power systems is necessary for system operators to detect potential problems and identify the corresponding solutions.

Many researches for visualizing data in power systems have been carried out. For instance, two techniques including time lapse type videos, also called animation loops, and Sparklines, were presented and used for displaying time varying data across wide area networks in [1]. In [2], several plots concerning visual analysis for presenting the spatio-temporal variations and couplings of power system oscillations using Synchrophasor data have been presented. References [3-5] provide advanced power-system visualization techniques that allow the system operators to monitor the real-time system operations and to verify the system security rapidly. In [6-9], the power system analysis software, Power Word, is employed to visualize the system data. It provides various visualizing data including power flows in transmission lines, trend charts, 3D diagrams and so on.

In the future, a large scale of renewable energy will be integrated into the Taiwan's power system, bringing huge challenges on power system analyses and congestion managements. For such a system, the control and monitor for many substations and electric devices are required. Therefore, this work develops a visualization interface for transmission congestions. The developed interface utilizes actual power system parameters in Taiwan to simulate and analyzes the transmission congestions, and the developed visualization techniques include the map to show the transmission system, status warning in colors in steady-state and N-1 contingencies, and system time lapse display.

2. General Visualization Techniques and Demonstrations

Visualization platform provides multiple techniques to measure power systems and monitor the real-time operations. References [3-15] have proposed numerous visualization techniques for power system applications. A power system is normally structured using a single line diagram that consists of buses, generators, loads, and transmission lines. Fig. 1 shows an example of a single line diagram using visualization techniques, which provides the information about generations and loads, the power flow direction, overloading, and the results of steady-state power flow. However, Fig. 1 cannot display the exact location of each power component, which is one of the drawbacks in this visualization case. Notably, the visualization technique allows system operators to drag monitor window to show different areas so that the displayed size of a single line diagram is not limited by the window sizes.

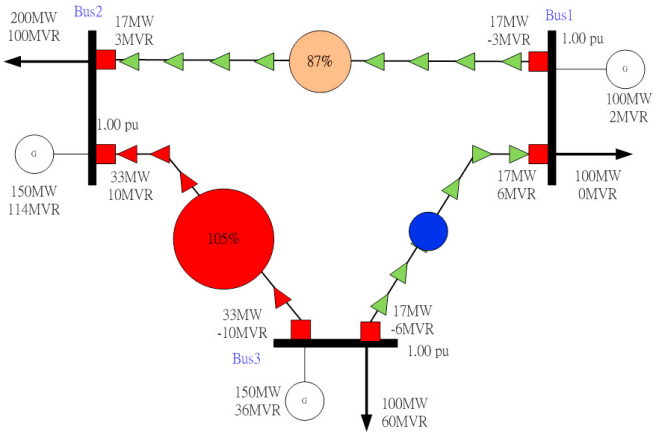

Fig. 1 Example of a 3-bus system

The main target of a visualization platform is to display the real-time operating status for a transmission system, especially for showing the direction of power flows and the current-carrying capacity. For instance, the presentation of a power flow describes the input and output power flow of each bus and presents the direction for power flow along the transmission line. However, the visualization of a large power system is not easy. Fig. 2 shows the single line diagram of a high voltage transmission system (345kV) at the Eastern North American [15]. For each line, the carrying current, rating, and direction of its power flow is displayed with different colors; the real power and reactive power in each line are also displayed. Another visualization method is to use dynamic pie chart to present

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